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Cincinnati, Ohio

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WATER QUALITY MANAGEMENT OF THE FUTURE

Whenever many of us in the field of public health think of the northeastern section of the United States, and specifically of the New England States, we are inclined to remember that this part of the country was and still is the home of much original and independent thought. This is exemplified by its pioneering in public health, by the continuous and successful development of its large educational institutions and by a characteristic independence in thought and action. A number of years ago, the term "Yankee ingenuity" was a common one in this section of the world. It was adopted by Worcester Polytechnic Institute in its "Yankee Ingenuity Scholarship". This unique grant is given annually to a high school student who has shown a consistent interest in science and has been able to develop and operate a mechanical device demonstrating a scientific principle. All of us owe a great deal to New England.

New England remains one of the major industrial centers of the country, even though much of its early industry has vanished. Newer and different industry has developed, and in the last 20 years the area has had a great increase in use of its natural resources for both industry and recreation. Water is not the least important of these resources.

The recent hearings before the Select Committee on National Resources of the United States Senate contain interesting reference to water quality management. In particular, there is the statement by the Hon. John F. Kennedy, Senator from Massachusetts, on the need

for increased attention to the problem of water pollution. Senator Kennedy's statement reads, in part, as follows: "We must pay increased attention to the problem of water pollution. The availability of clean water is of importance not only to our health and living standards, but to our industrial development as well. The early growth of New England was possible because there was plenty of good water available. Today pollution is the largest single destroyer of New England water resources, hindering the economic health and prosperity of the region". Senator Kennedy included this comment as one of five principles which he believes should be embodied in a water resources program.

At other points in the hearings, the matter of recreational use of water in New England was discussed. The hearings represent a good cross-section of thought on water resources problems of New England, and to some degree, cover many of the problems faced by other areas of the United States. Many of us hope that the traditional and effective "Yankee ingenuity" will help New England and all Regions to solve the difficult problems of water quality management of the present and the future.

The foresightedness of New England in developing protected watersheds for its municipal water supplies has long been recognized. Certainly it stands her in good stead now. But as the pressure for recreational use of water increases, the Nation finds itself moving away from completely protected watersheds. More and more frequently water supply impoundments are being opened to recreational use.

Concurrently, water treatment is increased as necessary. As New England searches for new economic bases to replace diminished ones, its attractiveness as a vacation land emerges with new importance. It appears now that New England will move rapidly toward recapturing the attractiveness and advantage of once undefiled surface waters. A sound plan and system for water quality management is essential to reach this objective.

Today water quality management in its broader sense is discussed in terms of the future, for it ~~is still~~ more a concept than a practice. The development of it as a practice is a major need and a major challenge of the next decade.

As I view it, water quality management of surface waters -- and I will limit considerations here to surface waters -- is a system for providing the right water quality at the right place. It embodies a set of procedures for keeping each segment of the surface water resource in the continuous dynamic balance necessary to meet the requirements of each significant use and next use. The concept may be considered quite simple, but the development of it in a form practical for application is definitely not simple.

The critical importance of water quality management stems, of course, from the great expanding demand for water against an essentially fixed supply. Only one-fourth of the average annual runoff, or about 314 billion gallons per day, is considered to be available at this time as dependable surface supply.[1] The

remaining three-fourths of runoff is in the familiar "wrong in time or place" category.

Depending on who is gazing into the crystal ball, this 314 BGD of water appears to be inadequate or more inadequate to meet future demands. If the hydrologists who estimate that about half of total runoff ultimately can be captured for use are correct, then we can look forward to a surface supply from this source of about 635 BGD. Augmentation further is possible in a number of ways: (1) through intelligent development of the great underground water reservoirs, (2) through desalination of ocean and brackish waters, (3) through reduction of evaporation, and (4) through weather modification. There are so many imponderables associated with these possibilities that predictions of their contributions to dependable supply are almost impossible. We can assume that they will provide some supplementation of the normal surface supply, but the amount and broad geographic availability of these supplies will not be such as to alter appreciably the national water picture.

Projections of water use over the next decade or two seem to be generally accepted -- the figure of 600 BGD for 1980, for example. Less reliable are the projections for the ensuing two decades, and such estimates as 1000 BGD by the year 2000 may be considered "best guesses".

As pointed out by the Senate Select Committee on National Water Resources[2], "it would appear on the surface that by the year

2000, total water use could exceed the limits of the Nation's developable fresh water supply resources". Counter to this view, they say, "this would not, in fact, be the case, however, because all of the various demands for water cannot simply be added together ...." The Committee Report goes on to point out that "water is used many times over" .... and that "the total of various purposes which can be served by a given quantity of water will vary from river basin to river basin ...."

The Senate report makes the point I wish to emphasize: "Water is used many times over". It will be necessary increasingly to re-use water, and the extent and type of re-use will vary from place to place and time to time. Whether the re-use be two, four, or six times, water quality management will be the key to meeting supply needs thereby. And the scientific basis of such water quality management is ability to measure substances in water, to understand their behavior in water, and to remove or avoid them economically when necessary.

I would like to turn now to some of the considerations of importance in water quality management of surface streams. From upland source to the ocean the stream is subject to both a series of withdrawals for use, and contributions from tributaries and underground supplies. Because some withdrawals involve consumption loss, the stream flow is reduced. Other withdrawals are almost completely returned, some slightly impaired in quality, some highly impaired and many in a condition between these extremes. Many uses and values

of the stream do not involve withdrawal at all -- the propagation of fish and wildlife, the recreational and aesthetic uses, and many other values are in the stream itself. Furthermore, these uses and values are not inconsequential. The views of Irving Fox in "Water - Supply, Demand and the Law"[3], are of interest here with respect to what he considers to be "the most arresting feature of the water supply-demand outlook, both East and West. It is the rapid increase in water use for recreation purposes and a growing recognition of the importance of preserving the aesthetic characteristics of the Nation's water resources. Since World War II, while the national economy has been growing at a rate of about 4 per cent a year, recreation use of water areas has been increasing at a much faster pace. For example, during this period, use of T.V.A. reservoirs increased at a rate of 15 per cent per year, while use of the reservoirs of the Corps of Engineers increased at a rate of 28 per cent per year. All signs now point to a tremendous increase in recreation water use during the next two decades. Since we now have about 20 million fishermen and approximately 5 million outboard motors, there can be no doubt about the economic importance of water-based recreation activity.

"But of even more significance than the economic activity which stems from recreation is the importance of outdoor play and relaxation to our highly urban and industrialized society. Yet the demand for clean waters is not related entirely to recreation. As forests and fields give way to factories, houses, and highways, and

as areas become more densely populated, it is increasingly important for lakes and streams to be aesthetically pleasing. As our society becomes more prosperous, as well as more densely populated, I anticipate a wide-spread insistent demand that the intrinsic beauty of the Nation's water resources be maintained".

The point of view expressed by Fox illustrates the wide range of quality control that we may be called upon to provide in the future. To date we have been more concerned with abating the inexcusably serious pollution conditions than with preserving clean waters. In the future it will be important to give more balanced attention to the total job of keeping water clean. The old adage of "an ounce of prevention ..." warrants serious attention. It should be more efficient and economical to plan water use to prevent impairment of the resource than to let use proceed uncontrolled and then try to correct the impairment.

Assuming that planned water use will be the order of the future, what do we need to know to control quality? First, of course, we must be able to measure pollution qualitatively and quantitatively. Analytical methodology is the first requisite to quality management. A water quality symposium held recently in Cincinnati reflected the present state of the art and science of water quality measurement. It showed that our present techniques are inadequate for current problems, to say nothing of future ones. It demonstrated, I believe, a need for methods and devices at least an order of magnitude better than today's for problems of the next

decade. As the number of substances in water increases, we shall have to be more discriminating in what we measure. Each parameter, old or new, should be critically evaluated so that the corresponding measurements will be most meaningful.

A further understanding of physical, chemical and biological forces and their interplay in the aquatic environment, is fundamental to effective water quality management.

Physical factors have not received appropriate attention from water quality scientists. As points of discharge and withdrawal are located closer and closer together, dispersion, turbulence, stratification, wind action and related factors will need more precise delineation from the standpoint of understanding, predicting and monitoring what takes place, and of designing better outfall and intake structures.

Certainly hydrodynamics will need more attention and application in the future. Sedimentation and transport of silts and other suspended matter have received much study and have been taken into account in the design of drainage, treatment and river structures. In spite of this, control of silts and debris has not been optimum. Most of us have seen streams of silt from construction sites, mining and agricultural operations, and trails of debris from timbering and related activities, and certain industrial operations. More ingenuity than we have applied in the past will be required for reduction of these impacts on our water resource. On the credit side of the ledger the progress made by the soil conservationists by

erosion control and other means is especially worthy of commendation.

Temperature will be more significant in the future. Power growth predictions point to added problems of thermal pollution. It will be a task of water quality management to develop the knowledge necessary to predict whether a given rise in temperature will promote or retard stream purification processes for wastes of varying character; what the effects on fish and related aquatic life will be; what the effect on growth of slimes and weeds will be. More reliable methods of forecasting the rate of heat loss under varying meteorological and hydrologic conditions will be needed.

More complicated than the physical are the chemical and biological aspects of water quality. We live in a chemical age, and its almost endless permutations and combinations are reflected in the water environment that receives its wastes. Separation and identification techniques and instrumentation are in only the primary stage. Our understanding is meager of the reaction kinetics of organic chemicals in dilute aqueous solution. Biochemical phenomena are reasonably understood only for the more sewage-like substances. Protracted or long range physiological effects of newer chemicals on man are hardly understood at all; the shorter term effects on aquatic life are almost as unknown, but we can assay lethality grossly. Here the need is obvious for more sensitive, quicker and less costly physiological assessment methods relating to both human and aquatic life.

Our understanding of biological operations in the water environment is mostly qualitative. It needs to move in the direction of quantitative understanding if biological measurements are to be incorporated in the system analysis matrix that will make possible tomorrow's water quality management.

A third major element of significance in water quality management is water cleaning technology. This includes the characterization of wastes, their removal or treatment, and the monitoring of effluents. Determination of the pollutional characteristics of wastes involves procedures for measuring their amenability to aerobic and anaerobic treatment, their fate in streams, their effect on the streams and stream life, their effect on and removal by water treatment processes and their effect on humans, plants and animals. Suggested characterizations of wastes have been in the literature for several years, but their general acceptance and use have lagged.

Likewise, the development of new treatment methods has lagged. Our water treatment methods are inadequate for the vigorous cleaning of waters likely to be required in the next 10 or 20 years. The most difficult problem appears to center around the removal of ions and molecules, particularly those of synthetic organic chemicals. This area of research demands much more attention than it is receiving now, for it is prerequisite to the successful reclamation and reuse of water needed in the future.

Up to now we have relied on the treatment capacity of receiving waters in greater or less degree. Probably we cannot

depend on using much of that assimilative capacity for the treatment of municipal and industrial wastes. Increasingly it will be required to accommodate that pollution from land use which is beyong sewerage and practice control: pesticide, and other commercial poison residues, natural and applied soil nutrients, eroded materials, and return irrigation contributions. Even with the most refined treatment of municipal and industrial wastes, we may be fortunate if any assimilative capacity of receiving streams is available as a safety factor. The significance of more advanced methods of waste treatment thus looms larger and larger. Better measurement tools to monitor residuals reaching our water courses will be more important as water quality balances become more delicate.

In order to "transistorize" the maze of scientific knowledge, which we hope to acquire, into its applied form -- wisdom -- we may need to reduce to a common discipline the various scientific languages of the physical, chemical and biological water worlds. Mathematics seems best suited to this purpose.

The first step then is to convert physical and biological knowledge to appropriate and workable mathematical expressions. This is, of course, not always easy to do in precise terms, especially for biological events. The limitations of mathematical expressions of biochemical oxygen demand and oxygen sag are familiar examples of the difficulty. The next step is to develop a mathematical matrix or model into which multiple variables can be fitted. Finally, systems analysis techniques are applied to solve problems presented

to the system. The whole process is one of accounting. It may be likened to a system of dynamic accounting where deposits, withdrawals, fluctuating values of assets, varying rates of simple and compound interest, and actuarial events are expressed continuously in terms of running balances and other management expressions essential to assessing and guiding an enterprise. It is somewhat in this fashion that I visualize the art and practice of effective water quality management emerging.

The resources behind the scene will be scientific staff, laboratories, instrumentation, basic data, measurement techniques, computer technology, and theoretical and applied mathematics. On the stage will be all of the competing and conflicting economic, political, social, legal, administrative and technical actors. In the audience are the critics, professional and lay, the jury, the public - striving to make sense out of the chaos, trying to separate fact from emotion, trying to separate basic issues from selfish interest, trying to identify the principles that can serve as firm foundation for law and practice.

The future significance of water quality is perhaps too obvious to belabor. We need it in developed form now in several areas of the country. As the water quantity squeeze becomes tighter and allocation doctrine and law are reshaped, reuse will increase and water quality control will assume greater if not critical importance.

The potential for development of water quality management practice is hinted in the extensive treatise on "Technology in American Water Development" published for Resources of the Future. With reference to conservation and quality control the authors say "Water quality control has not received the comprehensive attention technically possible. No administrative machinery has been in motion which examines all aspects of water quality on a basic wide scale, and applies measures of quality control, including paired use plans, on a unified basis to the watershed".

This commentary has all the flavor of an invitation for some one to fill the vacuum. As we look at reasons why no one has moved more aggressively to do so, we can see some of the same complications that may be responsible for unsuccessful efforts to develop national water policy. Aside from the lack of scientific knowledge there are so many interests, aspects and agencies involved that no one has been confident enough to take the lead or move alone.

We see constant reference to the inseparability of water management from soil and forest management. Yet something must come first, and there must be some place we can start on this most complex problem of developing the practice of water quality management. If we believe that good water is essential to national survival, that it is a "priceless" commodity, that it is the most critical factor affecting our economic development, then perhaps we must approach policy and practice development with the view that water quality objectives should be established first, and that water and land uses must be adjusted to fit these objectives.

Here again we will probably have to learn to walk before we run. The local setting offers a good place to begin. Starting with smaller and simpler river basin systems, we can inventory existing hydrologic, use and quality factors and attempt to set these in a framework or system for analysis. We can then challenge the system with hypothetical or predictable conditions of supply, demand, use, and reuse, and attempt to determine quality at points of significance in this dynamic system. As we acquire experience with simpler systems and identify and formulate the more critical variables, we can move on to more complex systems until we develop a methodology sophisticated enough to accommodate all the significant water quality management problems we expect to encounter in the future. This is a technical challenge of high order and one to which all of us are called to respond.

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